

Cost Estimation Structure for Research Reactor Spent Fuel Management

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CRP T33001 – “Options and Technologies for Managing the Back End of the Research Reactor Nuclear Fuel Cycle”

- Joint project with Waste Technology Section
- Initiated in 2014, completion in 2018
- Objective:
 - Identify the viable options available to MSs for their RR spent fuel management
 - Provide a **method** a MS can use to decide between options
- Expected Outputs:
 - Publication of CRP activities and results
 - Electronic (Excel-based) tools to assist MS with **spent fuel management cost estimating** and **option selection**
- 15 Participating MSs: Argentina, Australia, Brazil, Chile, France, Ghana, Jamaica, Malaysia, Greece, Norway, Portugal, South Africa, Slovakia, Russia, USA (2)

CRP Objectives

- Raise Awareness among Member States about RR SNF Management Responsibilities – for lifetime of the fuel
- Collect and Summarize Information on Current RR SNF Management Options
 - Focus on long term, permanent solutions
 - Developed technologies
 - Mature designs and analyses
 - Regulatory acknowledgement and support
 - Technical and economic information
 - Consider non-technical factors (political, public perception, etc.)
- Develop Cost Estimating and Decision Support Tools for Use by Member State Decision Makers

Research Reactor Spent Fuel Technologies



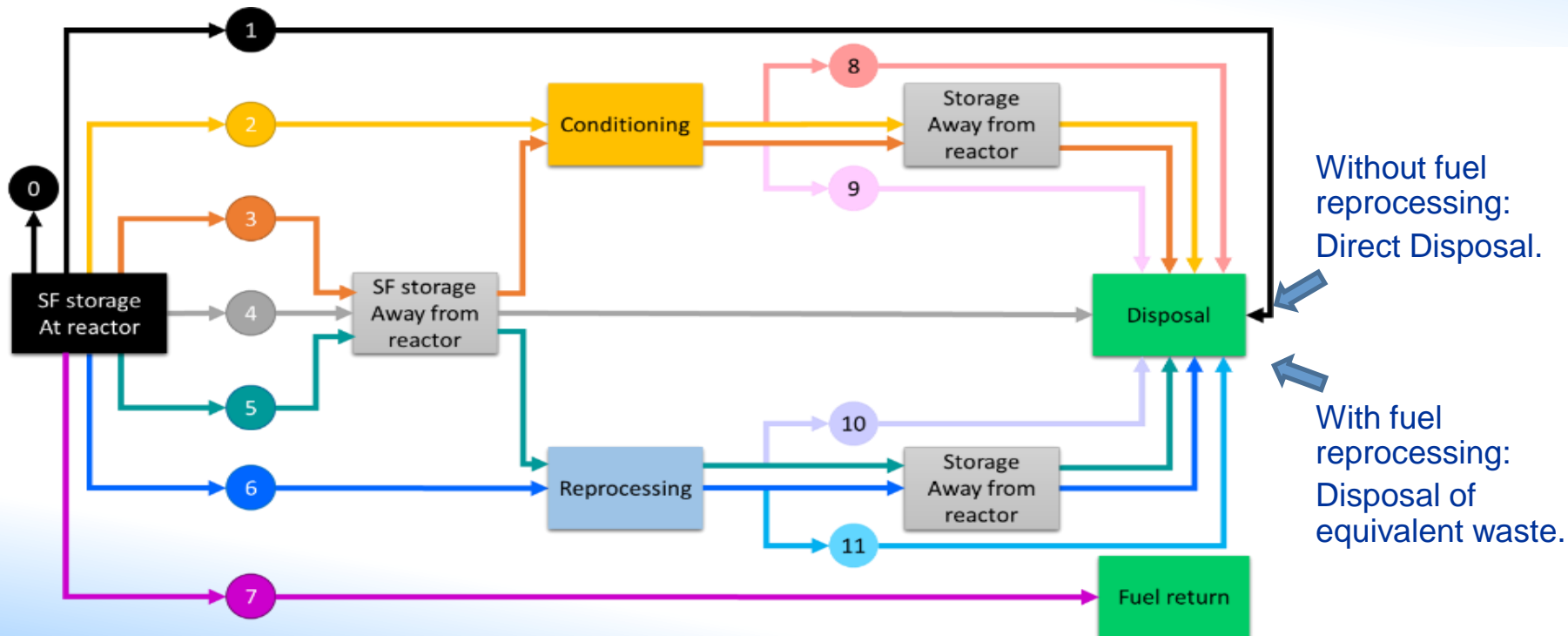
- Storage - Always considered temporary, i.e., not the final location of either the fuel or processing waste
 - Likely starts with wet storage – need good water chemistry management
 - Multiple storage locations could be used for one batch of fuel
 - At reactor
 - Away from reactor in national central location
- Conditioning - Modification of fuel assembly for packaging, transport, storage, or disposal
 - Fuel assembly cutting or compaction to reduce volume
 - Encapsulation into a matrix (e.g., glass or ceramic) for stability
- Reprocessing – removal of remaining fissile material and optimization (content and volume) of residual waste
- Transportation – Many licensed and commercially available containers
 - Most fuel assemblies (or residual waste) will have more than one transportation step – could use different containers
 - Containers can be dual use – storage and transportation
- Geological Disposal
 - Purpose-built mined repository
 - Deep boreholes
 - Converted mines

RR Spent Fuel Disposition Strategies

Combination of technologies create management strategies

- All Strategies Likely Need Multiple Transportation and Storage Steps
- Conditioning, then Disposal
- Processing, then Disposal
 - In same country as research reactor
 - In different country from research reactor
 - With some waste material return to reactor country
 - All waste and processing products stay in reprocessing country
- Geological Disposal
 - Practical for RRs if the country has nuclear power and already planning a geological repository
 - Regional disposal - Some MS express interest in the concept, no MS has expressed willingness to host

A Comprehensive Overview of RR Spent Fuel Management and Disposition Strategies

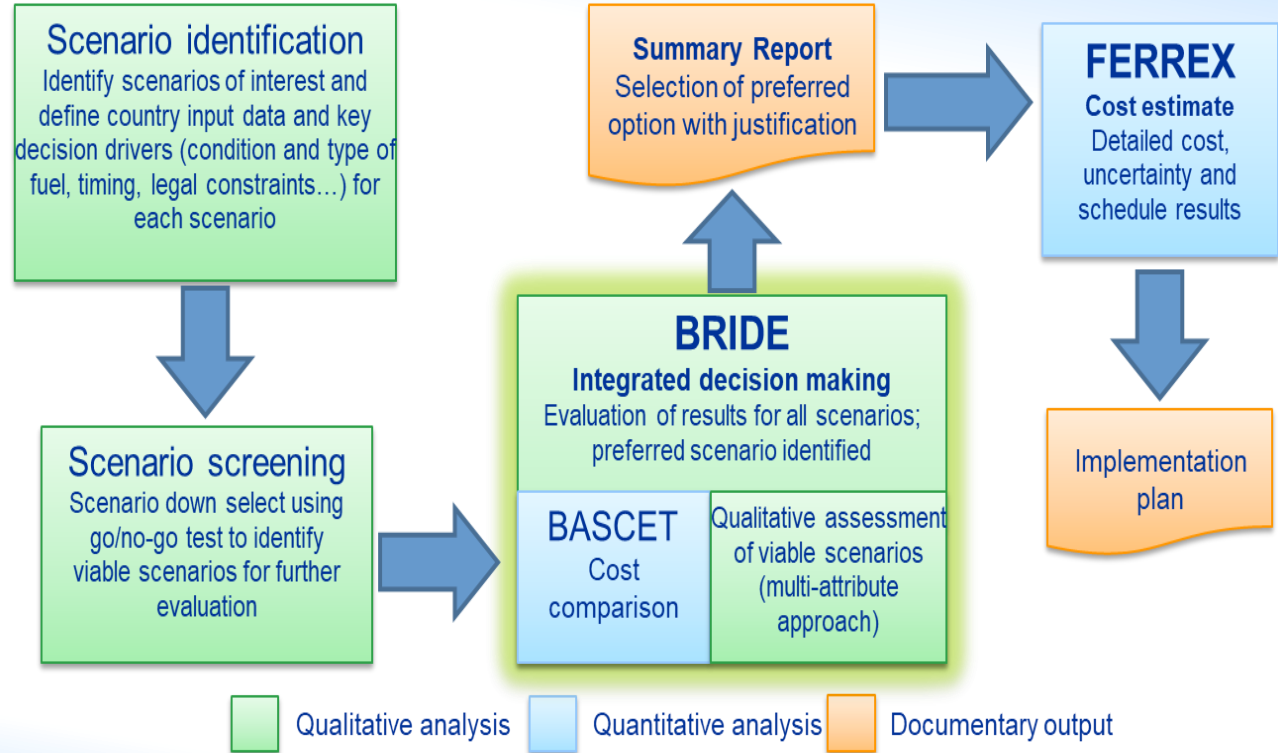
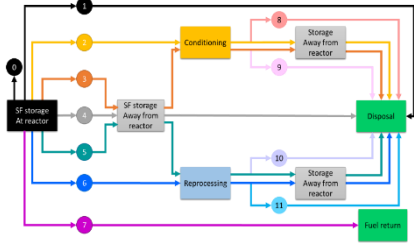


Which Strategy to Use? → Decision Support Tools



- BRIDE: Backend Research reactor Integrated Decision making Evaluation
 - Sub-routine BASCET: Backend Analytical Scenario Cost Estimation Tool
- Consideration of Non-economic Factors in Decision Making
 - Legal and regulatory considerations
 - Industrial and technical considerations
 - Political support
 - Public acceptance
 - Human resources
 - Environmental impact considerations
 - Regional and international partnerships
- Development of tool for cost estimation: FERREX - Fuel Cycle Cost Estimation for Research Ractors in Excel
 - Based on existing RR decommissioning cost estimating tool
 - Does NOT include cost database – commercial service costs are business sensitive and labor rates vary too widely among Member States to use for comparisons

Use of BRIDE and FERREX



Calculation Tool - FERREX

- **FERREX** - Fuel Cycle Cost Estimation for Research Ractors in Excel:
- Parallel to **CERREX** code - Cost Estimation for Research Ractors in Excel:
 - Developed within the IAEA to support the decommissioning costing of research reactors
 - Target users - countries with limited experience in decommissioning costing
 - Excel software - easy to use, no special training needed
- Same costing principles and methodology is used in FERREX and CERREX

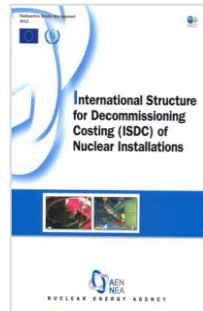
Standardized Costing Structure

- Common understanding of presented costs
- Understand the differences between the costing projects
- Transparency in costing
- Benchmarking of costs for different projects
- Avoiding inconsistency or contradictions in the results
- Facilitate communication

Decommissioning



ISDC (International
Structure for De-
commissioning Costing)



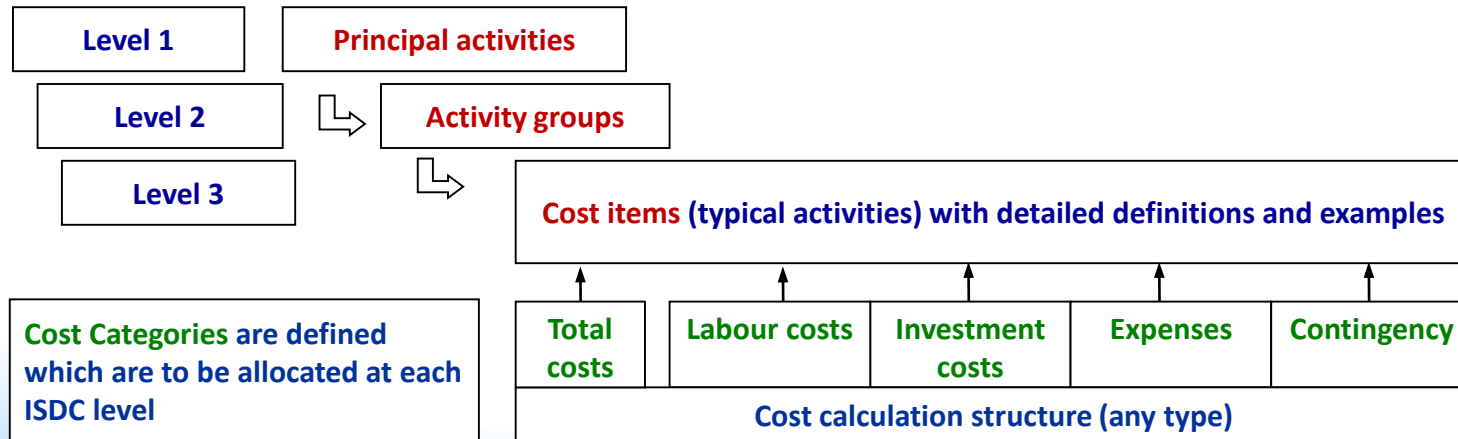
RR Spent Fuel Management



ISFC (International Structure for
Spent Fuel Cycle Costing of
Research Reactors)

What is ISDC (ISFC)?

- Project oriented, systematic **list of typical activities** developed for presenting the costs of various projects
- **Standardized hierarchical structure** with three numbered level aggregating the data bottom to top – opened down to the third numbered level, by costing unit (e.g., by time, person, fuel assembly)



ISFC Principal Activities – Level 1

- **01** Preparation of spent fuel management options
- **02** Spent fuel management activities at the reactor building
- **03** Long-term interim storage activities
- **04** Spent fuel return programs
- **05** Spent fuel reprocessing
- **06** Spent fuel stabilization
- **07** Disposal of the spent fuel and/or fuel-related radioactive waste
- **08** Packaging and transport of spent fuel and/or fuel-related radioactive waste
- **09** Management and support activities
- **10** Research and development
- **11** Miscellaneous costs

General Definition of RR Management Scenario

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Option 1: Domestic reprocessing followed by disposal of waste

- Amount of spent fuel to be managed:
 - Total number of fuel assemblies (FA): 200 FA
- General breakdown of the scenario (costing case) i.e. technologies and processes:
 1. Reactor defueling
 2. Characterisation of spent FA
 3. Long term storage at wet type of long term storage
 4. Domestic spent fuel reprocessing together with processing of waste from reprocessing
 5. Final disposal of reprocessed waste in the final repository
 6. Transport and packaging activities
 7. Preparation activities (documentation) - EXAMPLE: security planning study for transport of waste to final disposal facility
 8. Project management activities - EXAMPLE: management during reprocessing
 9. Miscellaneous costs - EXAMPLE: taxes paid during long-term storage and reprocessing

ISFC Activities 02 – Structure Example



02 Spent fuel management activities at the reactor building

02.0100 Defueling of the reactor core

- 02.0101 Preparation of reactor defueling
- 02.0102 Reactor defueling and transfer to spent fuel storage at reactor
- 02.0103 Support activities related to final defueling

02.0200 Management of old fuel already stored at the reactor building

- 02.0201 Design, construction / procurement of equipment and licensing
- 02.0202 Detailed planning of old spent fuel management
- 02.0203 On-site preparatory and support activities
- 02.0204 Implementation of activities related to old spent fuel management

02.0300 Management of damaged fuel

- 02.0301 Design, construction / procurement of equipment and licensing
- 02.0302 Detailed planning of damaged spent fuel management
- 02.0303 On-site preparatory and support activities
- 02.0304 Implementation of activities related to damaged spent fuel management

02.0400 Short term storage at reactor

- 02.0401 Modification or extending of existing short term storage at reactor
- 02.0402 Operation of short term storage at reactor
- 02.0403 Decommissioning of short term storage at reactor (if included in the SF management project)

ISFC Activities 09 – Structure Example



09 Management and support activities

09.0100 Project management and support for overall SF management

- 09.0101 Project management activities
- 09.0102 Project support activities

09.0200 Project management and support for defuelling and at-reactor activities

- 09.0201 Project management activities
- 09.0202 Project support activities

09.0300 Project management and support for spent fuel long-term storage

- 09.0301 Project management activities
- 09.0302 Project support activities

09.0400 Project management and support for spent fuel return programs

- 09.0401 Project management activities
- 09.0402 Project support activities

09.0500 Project management and support for spent fuel reprocessing

- 09.0501 Project management activities
- 09.0502 Project support activities

09.0600 Project management and support for spent fuel stabilization

- 09.0601 Project management activities
- 09.0602 Project support activities

09.0700 Project management and support for spent fuel and fuel related waste transport

- 09.0701 Project management activities
- 09.0702 Project support activities

09.0800 Project management and support for spent fuel and fuel related waste disposal

- 09.0801 Project management activities
- 09.0802 Project support activities

ISFC Methodology - ISFC Cost Elements



- **Activity-dependent costs:**
 - Directly related to the extent of “hands-on” work (characterisation, stabilisation, reprocessing, disposal, transport...)
 - Unit factors approach is applied (workforce or costs per ton, m³, container, fuel assembly, etc.)
- **Period-dependent costs:**
 - Activities associated primarily to duration and composition of the relevant workgroup
 - Examples: management, administration, engineering, planning, licensing
- **Collateral costs and costs for special items:**
 - Do not fall in either of the other categories
 - Procurement, insurances, taxes, one-off payments
- **Contingency:**
 - Specific provisions for unforeseeable elements of cost within the defined project scope

ISFC Methodology - Cost Categories



- ISFC defines four cost categories at level of each item:
 - Labour cost
 - Investment cost
 - Expenses
 - Contingency
- **Labour costs** are related to workload; it includes:
 - Salaries
 - Contributions to social security and health insurance
 - Company contributions to pension scheme and fringe benefits
 - Overheads
- **Investment costs** are costs for equipment, machinery or specific expensive materials
- **Expenses** are costs for consumer and expendable items
- **Contingency** is a specific provision for unforeseeable elements of costs within the **defined project scope**; Proper planned contingency is spent in the process
- When data on cost categories are not available, **presentation of total cost is also the option**
- **Presentation of workforce** and other project management data along with cost data is recommended

Expenses - examples

- *Consumables*
- *Spare parts*
- *Protective clothing*
- *Travel expenses*
- *Legal expenses*
- *Taxes*
- *Insurance*
- *Consultants costs*
- *Rents*
- *Office material*
- *Heating costs*
- *Water costs*
- *Electricity costs*
- *Computer costs*
- *Telephone/fax costs*
- *Cleaning*
- *Interest*
- *Public relations*
- *Licences/patents*
- *Decommissioning authorisation*
- *Income from asset recovery ("negative expenses")*

FERREX Basic Modules (spreadsheet outputs)

- **Lists:** presents the lists of used calculation cases
- **ISFC:** ISFC cost calculation core of the FERREX code
- **FCC_INV:** Definition of inventory for fuel cycle categories
- **ISFC L3:** Cost presentation table in ISDC Level 3 format
- **ISFC L2:** Cost presentation table in ISDC Level 2 format
- **ISFC L1:** Cost presentation table in ISDC Level 1 format
- **Schedule:** definition of the schedule for spent fuel management scenario
- **Cash flow:** time distribution of costs
- **Categories:** Summary of fuel cycle categories

Schedule – SF management scenario

Schedule – input data

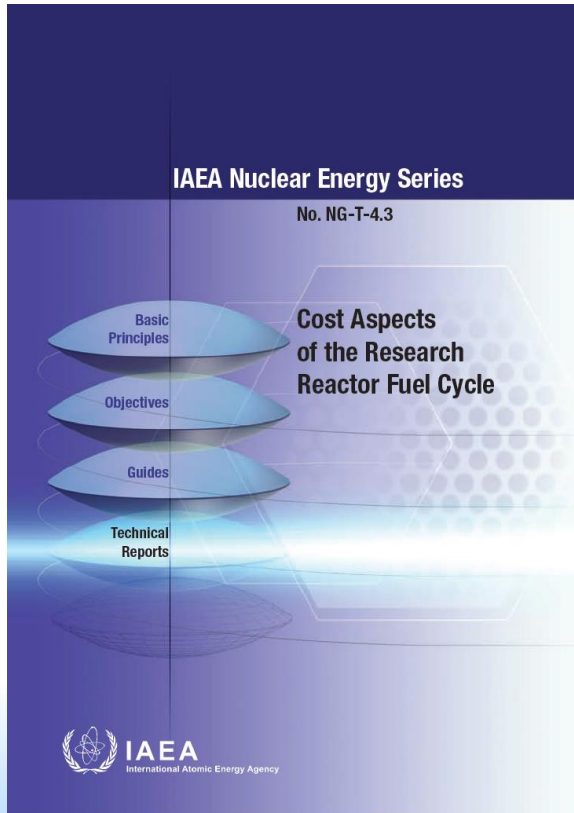
Activity	ISFC number	Duration (Y)	Start date
Fuel characterisation	01.0200	1	2020
Defueling of reactor core	02.0100	1	2020
Long term storage	03.0100	20	2021
Long-term storage - taxes	11.0300	20	2021
Reprocessing of SF	05.0200	3	2041
Reprocessing – management and support	09.0500	3	2041
Reprocessing - taxes	11.0500	3	2041
Transport – security planning	01.0300	1	2043
Transport to disposal facility	08.0900	1	2043
Final disposal of reprocessed waste	07.0500	3	2044

References for FERREX Development



- International Atomic Energy Agency, “Cost Estimate for Research Reactor Decommissioning,” Nuclear Energy Series, No. VW-T-2.4, Vienna (2013).
- OECD Nuclear Energy Agency, International Atomic Energy Agency, European Commission, “International Structure for Decommissioning Costing (ISDC) of Nuclear Installations,” OECD/NEA No. 7088, (2012).
- International Atomic Energy Agency, “Financial Aspects of Decommissioning, Report by an Expert Group,” IAEA-TECDOC-1476, IAEA, Vienna (2005).
- OECD Nuclear Energy Agency , The Practice of Cost Estimation for Decommissioning of Nuclear Facilities,” OECD/NEA No. 7237, (2015).

RR Cost Estimating Publication



- Cost estimation approach considers risk and liability
 - Technical risk – technology maturity
 - Performance risk – operational reliability of systems and regulatory stability
 - Commercial risk – financial fluctuations
- Identification of data gaps
- Establishment of system boundaries and assumptions

RR Spent Fuel Management Cost Estimating Summary

- Cost Estimating Knowledge Transferred from Decommissioning to RR SNF Management:
 - Created standardized structure - **ISFC**
 - Developed ISFC costing methodology
 - Developed **FERREX** calculation tool
- Available to Assist Member States in Development and Evaluation of Scenario(s) from the Detailed Costing Perspective:
 - Understanding and application of ISFC items and costing ISFC costing methodology
 - **Prepare costing case by using FERREX tool**
- Use of other risk analysis based project cost estimating tools

Thank you!

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